NRC·CNRC

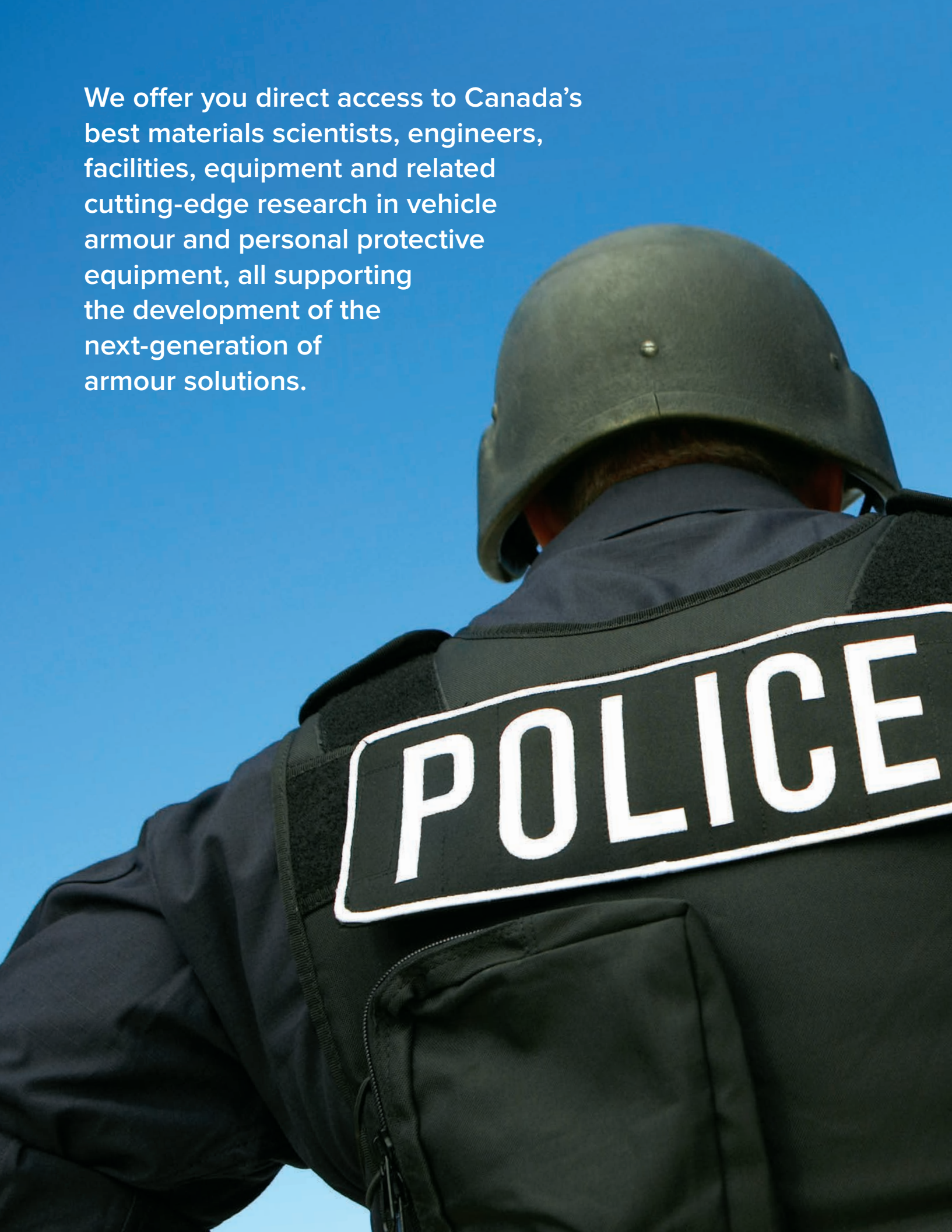
# Superior protection

## through advanced materials

Government of Canada / Gouvernement du Canada

Canada

We offer you direct access to Canada's best materials scientists, engineers, facilities, equipment and related cutting-edge research in vehicle armour and personal protective equipment, all supporting the development of the next-generation of armour solutions.



**It is only through new and advanced material technologies that significant gains in performance will be achieved. That's why the National Research Council of Canada (NRC) has joined forces with Defence Research and Development Canada (DRDC) to deliver the Security Materials Technologies (SMT) research program.**

The SMT program integrates key strengths and capabilities from both organizations. NRC is the only organization in Canada, and one of few in the world, with integrated world-class expertise in engineered materials, processing and performance currently focused on the design, testing and production of advanced protection products. For its part, DRDC has capabilities and experience in assessing and validating novel armour systems.

Collectively, NRC and DRDC have the experience to develop high-performance material solutions and multi-threat protection solutions.

We work directly with Canadian industry and other partners across the security materials supply chain to develop improved and disruptive, game-changing armour products from concept to full-scale prototyping and evaluation.

Our technical advice and consulting services are designed to help accelerate, and substantially de-risk product development.

## We can help you make better protection systems by:

- Improving the performance of conventional armour materials
- Developing new nano-modified or hybrid materials and armour structures
- Devising improved manufacturing and integration methods
- Accelerating development and validation of new products
- Assessing product performance through testing

## What we can provide

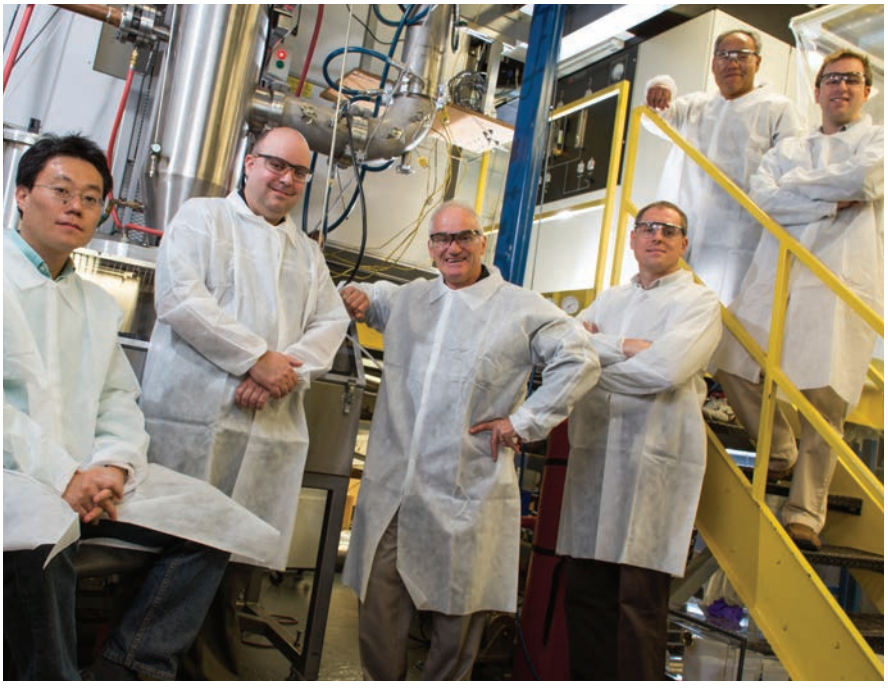
- Reduced risk and significant cost savings in product development
- More efficient use of your valuable resources and research investments
- More effective solutions in less time
- Exploitation and transfer of specialized knowledge

Our technical advice and consulting services help our partners succeed by capitalizing on NRC's and DRDC's extra-ordinary strengths in the science and engineering of advanced materials, manufacturing processes, and armour systems.

## Work with us

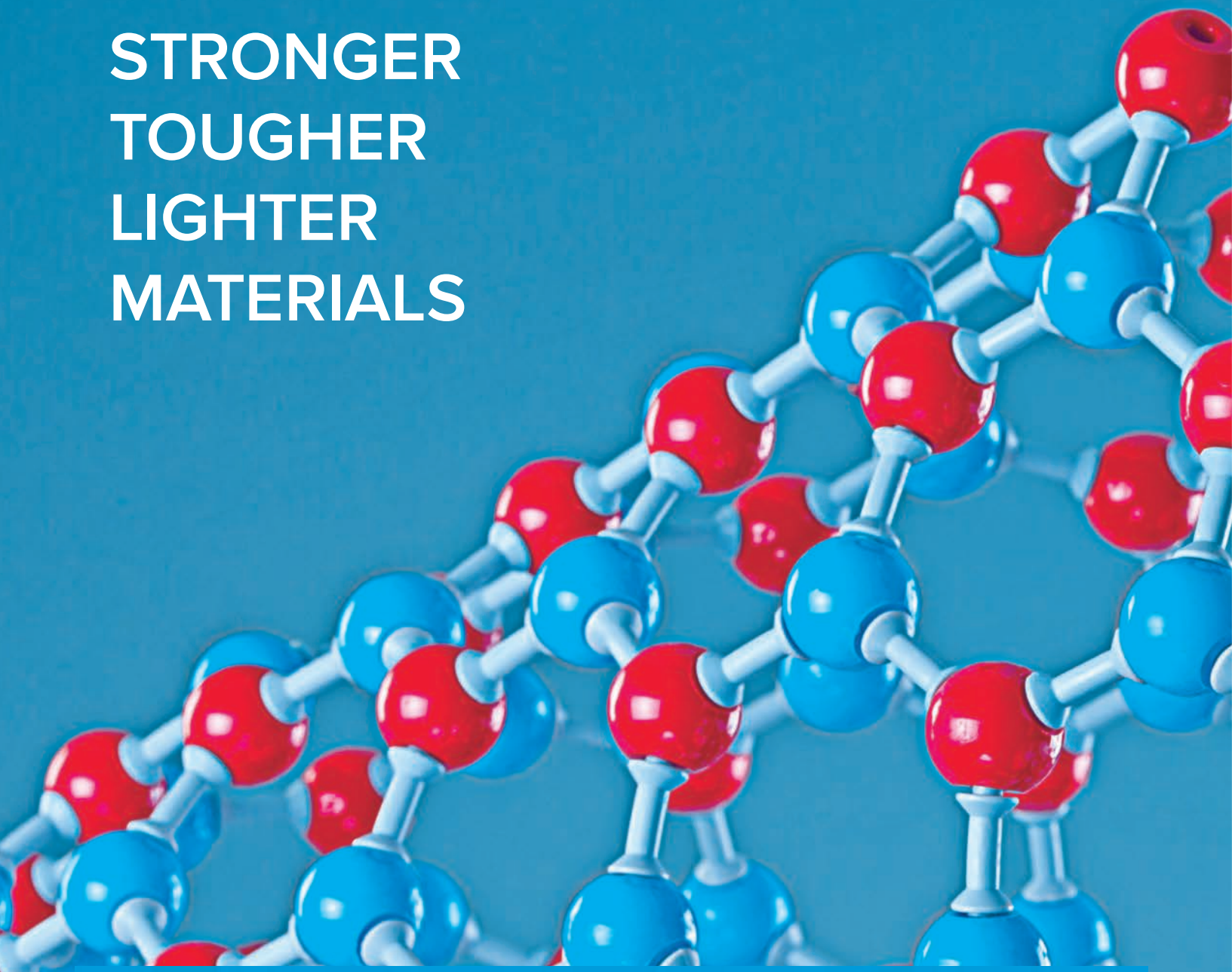
- Access extensive scientific knowledge and technical expertise – from constituent materials to armour components and systems
- Access critical and world-class research infrastructure from nano-scale to full-scale
- Develop unique customized solutions to maintain and improve your competitive edge

**NRC's nanocomposites group was awarded the 2015 Public Service Award of Excellence in the Scientific Contribution category for their breakthrough work enabling the world's first pilot-scale production of boron nitride nanotubes. L to R: Keun Su Kim, Mark Plunkett, Benoit Simard, Chris Kingston, Jingwen Guan, Mike Jakubinek**



MATERIALS TECHNOLOGIES

# STRONGER TOUGHER LIGHTER MATERIALS



## ABOUT COMPOSITES, HYBRIDS AND NANO-MODIFIED MATERIALS

**Composite material**
A combination of two or more materials with very different properties, which creates a new material with characteristics different from the individual constituents.

**Nanomaterials**
Materials with at least one dimension between 1 nm to 100 nm, often exhibiting extraordinary mechanical, thermal or other properties. Example: single-walled carbon nanotubes, with a diameter of about 1 nm, are over 100 times stronger than steel by weight.

**Nano-modified material**
A composite material with at least one constituent being a nano-material, imparting some of the extraordinary properties of the nanomaterial(s) to the composite, even at low concentrations (e.g. less than 1%).

**Hybrid material**
A type of composite material with two or more types of macroscopic (not nano-scale) constituents with quite different but complementary properties. For example, an aramid/carbon hybrid combines stiffness and ballistic resistance.

# Nanomaterials

**Improve and expand the performance of conventional and advanced materials**

Nanomaterials, such as carbon nanotubes (CNTs) and boron nitride nanotubes (BNNTs), can enhance the properties and functions of current materials and introduce new functionalities that weren't previously possible, allowing for the creation of new, more efficient and higher-performance material systems.

We have extensive scientific and engineering knowledge and experience manufacturing, handling and optimizing the integration of nanomaterials into conventional materials to produce high-performance materials and structures.

# Nano-modified materials and hybrids

Translating the extraordinary properties of nanomaterials into real-world armour applications requires effective integration into conventional high-performance armour materials. Our materials experts have applied their world-class skill sets in chemistry, physics, and process engineering to successfully nano-modify a broad range of materials including polymers, adhesives, textiles, metals, ceramics and glasses.

The resulting nano-modified engineered materials can show not only improved strength, stiffness and toughness compared to the base material, but can also be designed to improve flame and temperature stability, moisture resistance and electrical properties.

Some nano-modified materials are ready for near-term armour applications, while others will require longer term investments to reach their truly disruptive potential. In many cases, shorter-term benefits can be achieved through creative engineering of hybridized structures. Combining conventional engineering materials (e.g. aramid and carbon composites) in ways that leverage the best properties of each can create structures with greater performance than any single material. Our team possess the skills in design, materials, processing and manufacturing to develop optimized hybrid material systems for your application.

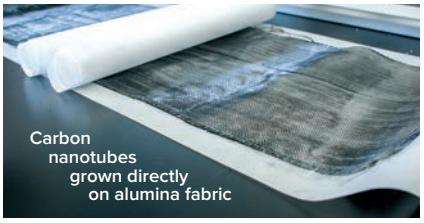
## Nanocomposite and hybrid materials can have a big effect on:

- Creating materials and structures with unique properties possessed by no single natural material
- Functionally-graded materials that transition from one property to another
- Materials designed for a specific threat environment
- Multi-functional materials that avoid parasitic weight of multiple layers with different functions
- Improved armour system performance

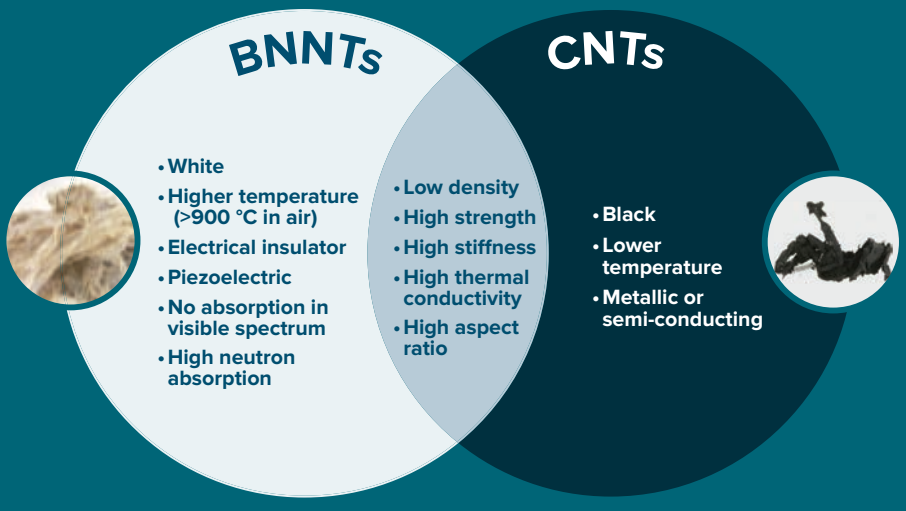
## Boron nitride nanotubes production capacity

The structural, electronic and optical properties of BNNTs make them promising candidates for nano-modification of polymers, glasses, metals and ceramics. BNNTs are expected to lead to lighter and multifunctional materials for applications in aerospace, automotive, and defence and security. Of particular interest is the potential of BNNTs as coatings or for bulk modification of transparent armour.

In 2015, NRC signed a licensing agreement with Tekna Plasma Systems Inc. allowing Tekna to manufacture BNNTs in commercial quantities using NRC-developed methods. The patented technology produces BNNTs over 100 times faster than any earlier methods, opening the door to exploration of BNNTs in a wide range of applications.


Carbon nanotubes grown directly on alumina fabric

**BNNTs and CNTs each have unique multifunctional advantages and share similarly impressive mechanical properties**



PROCESSING & MANUFACTURING

# FLEXIBLE SCALABLE INDUSTRIAL PROCESSES

## Modelling

Our capabilities allow modelling and simulation of processing, properties and performance of materials and structures from the nano-scale to full-scale. These capabilities can substantially reduce materials and process development time, and de-risk product development.

**Our modelling tools help to explore a wide range of challenges**

- Manufacturing process development
- Environmental durability and degradation
- Damage initiation and propagation
- Translating nano-scale performance to macro-scale structures
- Low to high-speed velocity impacts
- Blast and structure interactions
- Vehicle control and dynamics

## Manufacturing

High-quality, repeatable and cost-effective manufacturing processes are critical in order to successfully transition the next generation of high-performance materials into successful armour products.
We have extensive knowledge of advanced processing and manufacturing technologies.
Our world-class expertise includes nanomaterials production and integration, joining technologies, polymers and advanced composites processing, metals and ceramics processing, coatings technologies, non-destructive inspection and additive manufacturing.

We can manufacture a broad range of materials and select the best processing route for combining polymers with reinforcing fabrics. These include wet and pre-impregnated layups, micro foaming, compression moulding, resin transfer moulding, injection moulding, reaction injection moulding, profile and sheet extrusion, film blowing, continuous fibre reinforcement, filament winding, etc.

Whether we add nanoparticles to the polymers or other additives, the end result is a polymer composite in a form that can be shaped into personal protective equipment (PPE) or vehicle armour (VA).

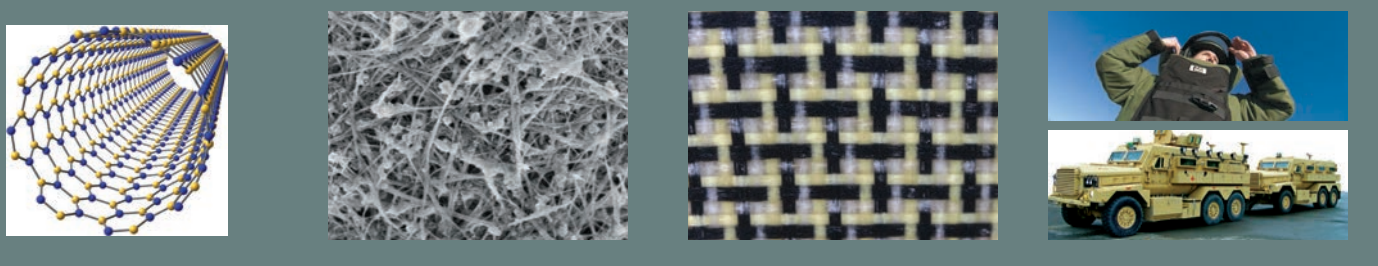
At the core of our armour products manufacturing capabilities is the Hot Press, a multi-process moulding platform. In addition to an infra-red oven, it boasts an array of features such as high speed ram movements and rapid heating capabilities.

Our team has decades of experience developing and transitioning state-of-the-art manufacturing technologies to industry, particularly in the aerospace, automotive and ground transportation sectors. We will work with you to rapidly identify the best manufacturing route for your product, and to develop and demonstrate a process that can be quickly transitioned to your own operation or your supply chain.

## Scale-up production of nano-modified materials

A challenge common to all new materials is scaling up from lab-scale demonstrators to industrial production. We are expanding our facilities and tools for the production, processing, formulating and integration of nanomaterials and nano-composites to fill this critical gap. Scale-up of these novel nano-modified materials to industrially relevant quantities enables thorough process trouble-shooting and optimization in preparation for transfer to full-scale production lines. It also feeds our advanced manufacturing facilities with quantities of nano-modified materials sufficient for large-scale component manufacturing and prototype demonstrations.

Commercial prototyping at the NRC Boucherville facility




**FROM NANOMATERIALS TO VALIDATED PRODUCTS**

ARMOUR SYSTEMS

# STRONGER TOUGHER, LIGHTER & COST-EFFECTIVE

# Personal protective equipment and vehicle armour

**Through the Security Materials Technologies program, we support the development, assessment and adaptation of next-generation materials and manufacturing technologies to enhance the performance and reduce the weight of PPE and VA.**

### Maximize effectiveness and reduce costs

We are developing a range of materials and manufacturing technologies leading to improved, cost-effective PPE and VA components and systems. One example is our efforts to adapt an automotive technology called direct long-fibre thermoplastics (D-LFT) to design low-cost, high-complexity armour from long discontinuous aramid fibres. Another area of work is the application of our world-leading BNNT technologies to improve polymer transparent armour through both more durable surface coatings and bulk material modification. In all cases, whether meeting a short-term client requirement or addressing longer-term challenges, our work is aimed at transitioning advanced armour technologies to Canadian industry.

If you manufacture PPE, VA, transparent armour components and systems, or armoured vehicles themselves, and you want to strengthen your position in the marketplace, the SMT team can:

- introduce you to new materials and manufacturing technologies to support your mission;
- identify ways to improve your existing products and manufacturing processes;
- introduce you to the state-of-the-art in computer modelling of ballistic and blast processes, and establish the extent to which they can help you optimize the performance of your products;
- help you establish linkages with key suppliers and partners;
- introduce you to test organizations that can evaluate ballistic or blast performance of your components, products and systems; and
- work with you on ITAR or non-ITAR technologies.

**Modern armour systems are the result of complex system engineering processes that balance mobility, lethality, protection and cost to respond to evolving threats and operational requirements. Rapidly advancing materials technologies and a highly competitive global armour industry makes it challenging for companies to stay on top.**

# CHARACTERIZATION & TESTING FACILITIES

**Our clients and partners have the opportunity to access our innovative research facilities to develop products and get them into the hands of customers better and faster than before.**

- Unparalleled industrial materials processing facilities
- Versatile mechanical testing facilities
- Access fast and cost-effective analytical services

## MATERIALS CHARACTERIZATION SERVICES AT A GLANCE

**MECHANICAL CHARACTERIZATION**
- Micro- and nano-hardness testers
- Adhesion tests such as shock wave
- Mechanical test rigs from micro-scale to full-scale

**PHYSICAL AND CHEMICAL CHARACTERIZATION**
- World-class electron microscopy
- Chemical analysis
- Thermal and electrical properties
- Flame resistance

**NON-DESTRUCTIVE MATERIALS TESTING**
- Conventional and laser-ultrasonic, radiographic, photometric, and computed tomography

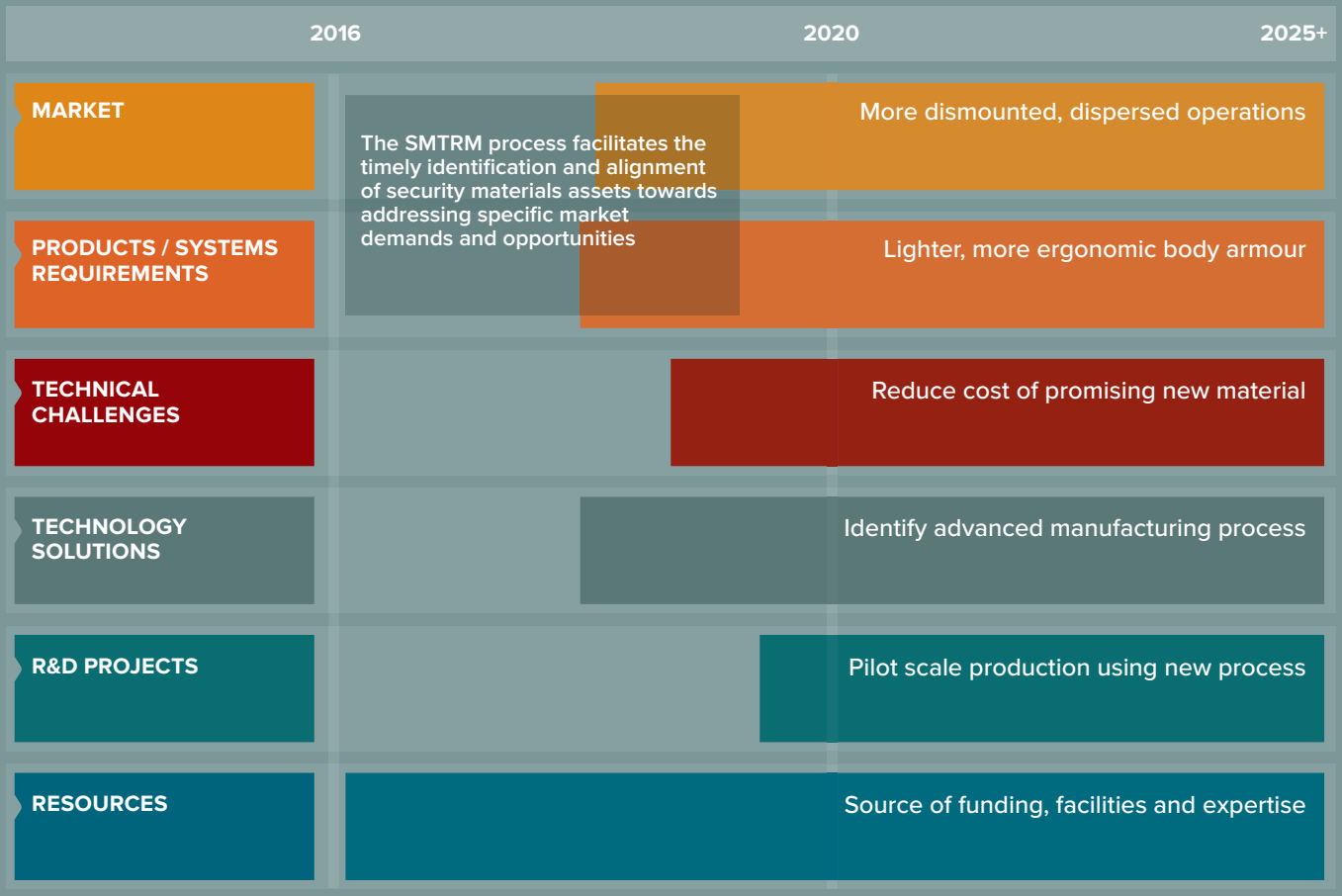
**ENVIRONMENTAL CONDITIONING**
- Immersion tanks
- Environmental and thermal aging chambers
- UV resistance

**NON-CONTACT STRAIN MEASUREMENTS**
- Advanced digital image correlation (high speed)

**POLYMER CHARACTERIZATION**
- Rheological properties
- Thermal properties
- Morphology

**DYNAMIC STRUCTURAL CHARACTERIZATION**
- Blast and quasi-static pressure with air cannons, shock tubes, and explosive devices
- Low-to-high velocity ballistic impact tests from less than 15 m/s to beyond 3000 m/s with two-stage gas guns, plate impact testers, high-speed recording devices, and enhanced laser velocity systems

# SECURITY MATERIALS TECHNOLOGIES ROADMAP




**VISION • provide timely, effective, affordable and integrated solutions for vehicle armour and personal protective equipment in Canadian and global markets.**

The Security Materials Technologies Roadmap (SMTRM) enables industry, end-user and research stakeholders to coordinate their combined resources to quickly and effectively meet current and future armour system challenges. The roadmap addresses ever-evolving threats, operational requirements, fiscal realities and global market opportunities in vehicle and personal armour systems through timely, prioritized, research, development and demonstration.

**Connect with the SMTRM if:**

- Your operations require more from your armour systems.
- You are seeking to develop more competitive armour products or systems for local or international markets.
- You have expertise or facilities in one or more of our technology areas of focus.

**Get on the map!**
defenceandsecurity.ca/cms3/our-resources


## Five powerful reasons for collaborating with us

1. **Create competitive armour products:** Keep up with and surpass global competitors.
2. **Get products to market faster:** Shorten the time it takes to integrate new high-performance materials technologies into personal and vehicle armour systems.
3. **Gain access to world-class research infrastructure and unique expertise:** We provide an opportunity to access unique capabilities and facilities.
4. **Enjoy intellectual property terms that match risks and levels of investment:** Our goal is to support Canadian defence and security companies in becoming international market leaders and our intellectual property policies supports companies in doing so.
5. **Stay visible and connected within the Canadian defence and security community:** Our program gives companies the chance to interact with peers and influence government investments.

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